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Longley-Rice Methodology

for

Evaluating TV Coverage and Interference

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IV. FREQUENTLY ASKED QUESTIONS

Dipole Factor

HAAT Column of Table 1, Appendix B, *Sixth Report and Order*

This Bulletin provides guidance on the implementation and use of Longley-Rice methodology for evaluating TV service coverage and interference in accordance with Sections 73.622, 73.623 and 74.704 of the FCC rules.

The Longley-Rice radio propagation model is used to make predictions of radio field strength at specific geographic points based on the elevation profile of terrain between the transmitter and each specific reception point. A computer is needed to make these predictions because of the large number of reception points that must be individually examined. Computer code for the Longley-Rice point-to-point radio propagation model is published in an appendix of NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. Some modifications to the code were described by G.A. Hufford in a memorandum to users of the model dated January 30, 1985. With these modifications, the code is referred to as Version 1.2.2 of the Longley-Rice model. This version is used by the FCC for its evaluations.

The Bulletin is divided into four parts. Section I provides information on evaluating TV service area or coverage. Section II provides information on evaluating interference to the service areas of both analog NTSC and digital television (DTV) stations. Section III provides information on implementation of the FCC's Longley-Rice Computer program. Finally, Section IV provides answers to frequently asked questions.

I. EVALUATION OF SERVICE

The Area Subject to Calculation

Under the FCC's rules, computation of service area or coverage using the Longley-Rice methodology is limited to the areas within certain specific geographic contours.

For analog TV, computations are made inside the conventional Grade B contour defined in Section 73.683 of the FCC rules, with the exception that the defining field for UHF channels is modified by a dipole factor equal to 20 log[615/(channel mid-frequency)]. Thus the area subject to calculation for analog TV consists of the geographic points at which the field strength predicted for 50% of locations and 50% of time by FCC curves is at least as great as the

values given in Table 1 below. The relevant curves for predicting these fields are the F(50, 50) curves found in Section 73.699 of FCC rules.

For digital television stations, service is evaluated inside contours determined by DTV planning factors in combination with field strength curves derived for 50% of locations and 90% of the time from curves which are also found in Section 73.699 of FCC rules. The family of FCC propagation curves for predicting field strength at 50% of locations 90% of the time is found by the formula F(50, 90) = F(50, 50) - [F(50, 10) - F(50, 50)]. That is, the F(50, 90) value is lower than F(50, 50) by the same amount that F(50, 10) exceeds F(50, 50).

Table 1.

Field Strengths Defining the Area Subject to Calculation for Analog Stations

Channels	Defining Field Strength, dBu, to be predicted using F(50, 50) curves
2 - 6	47
7 - 13	56
14 - 69	64 - 20 log[615/(channel mid-frequency)]

The defining field strengths for DTV service, contained in Section 73.622 of the FCC rules, are shown in Table 2. These values are determined from the DTV planning factors identified in Table 3. They are used first to determine the area subject to calculation using FCC curves, and subsequently to determine whether service is present at particular points within this area using Longley-Rice terrain-dependent prediction.

Table 2.

Field Strengths Defining the Area Subject to Calculation for DTV Stations

Channels	Defining Field Strength, dBu, to be predicted using F(50, 90) curves
2 - 6	28
7 - 13	36
14 - 69	41 - 20 log[615/(channel mid-frequency)]

For digital TV three different situations arise:

1) For DTV stations of the initial allotment plan located at the initial reference coordinates, the area subject to calculation extends in each direction to the distance at which the field strength predicted by FCC curves falls to the value identified in Table 2. The bounding contour is identical, in most cases, to that of the analog station with which the initial allotment is paired. The initial allotment plan and reference coordinates are set forth in Appendix B of the *Sixth Report and Order* in MM Docket 87-268, FCC 97-115, adopted April 3, 1997.

2) For new DTV stations, the area subject to calculation extends from the transmitter site to the distance at which the field strength predicted by FCC curves falls to the value identified in Table 2.

3) In the case where a DTV station of the initial allotment plan has moved, the area subject to calculation is the combination (logical union) of the area determined for the initial allotment and the area inside the contour which would apply in the case of a new DTV station.

Planning Factors

The planning factors shown in Table 3 lead to the values of field strength given above in Table 2 to define the area subject to calculation for DTV stations. These planning factors are assumed to characterize the equipment, including antenna systems, used for home reception. They determine the minimum field strength for DTV reception as a function of frequency band and as a function of channel number in the UHF band.

Table 3.

Planning Factors for DTV Reception

Planning Factor	Symbol	Low VHF	High VHF	UHF
Geometric mean frequency (Mhz)	F	69	194	615
Dipole factor (dBm-dBu)	K_d	-111.8	-120.8	-130.8
Dipole factor adjustment	K_a	none	none	see text
Thermal noise (dBm)	N_t	-106.2	-106.2	-106.2
Antenna Gain (dB)	G	4	6	10
Downlead line loss (dB)	L	1	2	4
System noise figure (dB)	N_s	10	10	7
Required Carrier/Noise ratio (dB)	C/N	15	15	15

The adjustment, $K_a = 20 \log[615/(\text{channel mid-frequency})]$, is added to K_d to account for the fact that field strength requirements are greater for UHF channels above the geometric mean frequency of the UHF band and smaller for UHF channels below that frequency. The geometric mean frequency, 615 MHz, is approximately the mid-frequency of channel 38.

The modified Grade B contour of analog UHF stations is determined by applying this same adjustment factor to the Grade B field strength given in 47 CFR §73.683. With this dipole factor modification, the field strength defining the Grade B of UHF channels becomes 64 - 20 log[615/(channel mid-frequency)] dBu, in place of simply 64. Thus the modified Grade B contour for channel 14 is determined by a median field strength of 61.7 dBu, and the value for channel 51 is 66.3 dBu. The modified values have been presented above in

Table 1. This modified Grade B contour bounds the area subject to Longley-Rice calculations for analog stations.

The values appearing in Table 2 follow from the planning factors. They were derived from Table 3 by solving the equation: Field + K_d + K_a + G - L - N_t - N_s = C/N.

For a new DTV station with a particular authorized set of facilities, the values given in Table 2 will determine the contour within which the FCC will make all subsequent calculations of service and interference.

Reference Value of ERP for DTV Operation

The initial allotment plan establishes a reference value for the effective radiated power (ERP) of DTV stations. This ERP is the maximum of the values needed to match the service contour of the paired analog station in each direction supposing that the new station operates at the same location with the same antenna height. The reference ERP was calculated using the following methodology:

The distance to the existing analog grade B contour was determined in each of 360 uniformly spaced compass directions starting from true north using linear interpolation of available data as necessary. This determination was made using information in the FCC Engineering Data Base of April 3, 1997, including directional antenna data, and from terrain elevation data at points separated by 3 arc-seconds of longitude and latitude. FCC curves (Section 73.699 of FCC rules) were applied in the usual way, as described in Section 73.684 of the rules, to find this grade B contour distance, with the exception that dipole factor considerations were applied to the field strength contour for UHF.

Height above average terrain was determined every 45 degrees from terrain elevation data in combination with the height of the transmitter radiation center above mean sea level, and by linear interpolation for compass directions in between. In cases where the TV Engineering Data Base indicates that a directional antenna is employed, the ERP in each specific direction was determined through linear interpolation of the relative field values describing the directional pattern. (The directional pattern stored in the FCC Directional Antenna Data Base provides relative field values at 10 degree intervals and may

include additional values in special directions. The result of linear interpolation of these relative field values is squared and multiplied by the overall maximum ERP listed for the station in the TV Engineering Data Base to find the ERP in a specific direction.)

The corresponding values of ERP for DTV signals in each direction were then calculated by a further application of FCC curves, with noise-limited DTV coverage defined as the presence of the field strengths identified in Table 2 at 50% of locations and 90% of the time. These ERP values were computed for all 360 azimuths using the same radial-specific height above average terrain as for the analog TV case, but now in conjunction with F(50, 90) curves.

Finally, the ERP for DTV was modified so that it does not exceed 1 megawatt and is not less than 50 kilowatts. This was been done by scaling the azimuthal power pattern rather than by truncation. Thus if replication by FCC curves as described above requires an ERP of 2 megawatts, the power pattern is reduced by a factor of 2 in all directions. The resulting ERP is the reference value cited in Section 73.622 of the rules.

DTV Transmitting Antenna Patterns

In general, these computations of DTV power to match the distance to the Grade B contour of an analog station result in ERP values which vary with azimuth. For example, the azimuthal ERP pattern which replicates in UHF the Grade B contour of an omnidirectional VHF operation will be somewhat distorted because terrain has a different effect on propagation in the two bands. In addition, the 90% time variability allowance for DTV has an effect on the DTV pattern. Thus the procedure described above effectively derives a new directional antenna pattern wherever necessary for a precise match according to FCC curves.

These DTV azimuthal patterns may be calculated using the procedure outlined above. In addition, they are available from the the FCC's internet site, www.fcc.gov, to supplement the information contained in Appendix B of the *Sixth Report and Order*. The format for describing DTV transmitting antenna patterns is identical to that of the FCC Directional Antenna Data Base for analog stations. Relative field values are given at intervals of 10 degrees, and supplemental values are given at special azimuths. For DTV patterns, special

azimuths are included where the pattern factor is unity while both bracketing factors at 10-degree azimuths are less than unity.

Application of the Longley-Rice Methodology

The area subject to calculation is divided into rectangular cells, and the Longley-Rice point-to-point propagation model Version 1.2.2 is applied to a point in each cell to determine whether the predicted field strength is above the value found in Table 1 or Table 2, as appropriate. The values identified in those tables are considered to be thresholds for reception in the absence of interference. For cells with population, the point chosen by the FCC computer program is the population centroid; otherwise it is the geometric center; and the point so determined represents the cell in all subsequent service and interference calculations. The station's directional transmitting antenna pattern, if any, is taken into account in determining the ERP in the direction of each cell. Cells 2 kilometers on a side were used to produce the service and interference data appearing in Appendix B of the *Sixth Report and Order.*

Those desiring to implement the Longley-Rice model in their own computer program to make these calculations should consult NTIA Report 82-100, *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, authors G.A. Hufford, A.G. Longley and W.A. Kissick, U.S. Department of Commerce, April 1982. The report may be obtained from the U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia, by requesting Accession No. PB 82-217977.

Parameter values set in the Longley-Rice Fortran code as implemented by the FCC are given in Table 4. In addition to these parameters, execution of the code requires a specification of the percent of time and locations at which the predicted fields will be realized or exceeded, and a third percentage identifying the degree of confidence desired in the results. To predict TV service at cells of the area subject to calculation, the FCC sets the location variability at 50% and the time variability at 90%. The percent confidence is set at 50%, indicating that we are interested in median situations. All of these values are the same as those used in the computer program developed by the Broadcasters' Caucus.

Table 4.

Parameter Values Used in FCC Implementation of the Longley-Rice Fortran Code

Parameter	Value	Meaning/Comment
EPS	15.0	Relative permittivity of ground.
SGM	0.005	Ground conductivity, Siemens per meter.
ZSYS	0.0	Coordinated with setting of EN0. See page 72 of NTIA Report.
EN0	301.0	Surface refractivity in N-units (parts per million).
IPOL	0	Denotes horizontal polarization.
MDVAR	3	Code 3 sets broadcast mode of variability calculations.
KLIM	5	Climate code 5 for continental temperate.
HG(1)	see text	Height of the radiation center above ground.
HG(2)	10 m	Height of TV receiving antenna above ground.

HG(1) in Table 4 is the height of the radiation center above ground. It is determined by subtracting the ground elevation above mean sea level (AMSL) at the transmitter location from the height of the radiation center AMSL. The latter is found in the TV Engineering Data Base while the former is retrieved from the terrain elevation data base as a function of the transmitter site coordinates also found in the TV Engineering Data Base. If the coordinates are wrong, the antenna may be seen as under ground. This shouldn't happen, but if it does, the FCC computer program replaces the radiation center height AMSL with the ground elevation at the given coordinates plus the height above average terrain found for the station in the TV Engineering Data Base.

Finally, terrain elevation data at uniformly spaced points the between transmitter and receiver must be provided. The FCC computer program is linked to a terrain elevation data base with values every 3 arc-seconds of latitude and longitude. The program retrieves elevations from this data base at regular intervals with a spacing increment which is chosen at the time the program is compiled. The computer runs which evaluated service and interference for the *Sixth Report and Order* used a spacing increment of 1 kilometer. The elevation

of a point of interest is determined by linear interpolation of the values retrieved for the corners of the coordinate rectangle in which the point of interest lies.

Evaluations of service coverage and interference using finer spacing increments are expected to be consistent with those using 1 kilometer. Evaluations using cells smaller than 2 km on a side are also expected to be consistent with the evaluations given in Appendix B of the *Sixth Report and Order.*

II. EVALUATION OF INTERFERENCE

The presence or absence of interference in each grid cell of the area subject to calculation is determined by further application of Longley-Rice. Radio paths between undesired TV transmitters and the point representing each cell are examined. The undesired transmitters included in the analysis of each cell are those which are possible sources of interference at that cell, considering their distance from the cell and channel offset relationships. For each such radio path, the Longley-Rice procedure is applied for median situations (that is, confidence 50%), and for 50% of locations, 10% of the time.

The interference analysis examines only those cells that have already been determined to have a desired field strength above the threshold for reception given in Table 1 for analog stations and Table 2 for DTV stations. A cell being examined is counted as having interference if the ratio of the desired field strength to that of any one of the possible interference sources is less than a certain critical minimum value. The comparison is made after applying the discrimination effect of the receiving antenna. The critical value is a function of the channel offset relationship.

Cells of the area subject to calculation for an analog station are examined first as to whether the desired signal is above the threshold for reception, second with regard to whether there is interference from another analog station, and finally as to whether there is interference from DTV stations. Thus a DTV station does not cause interference to analog stations in places where there is no service because of a weak desired signal, or in places where interference from other analogue stations already exists.

D/U Ratios

Criteria for the ratio of desired to undesired field strength are specified in Section 73.623 of FCC rules for interference involving DTV stations as desired or undesired. These criteria are summarized in Tables 5A and 5B.

Tables 5A and 5B also include the criteria for interference between analog stations used in preparing the service and interference evaluation in Appendix B of the *Sixth Report and Order*. The FCC will continue to apply an analog-into-analog interference analysis using these criteria for consistency with the *Sixth Report and Order*. DTV stations will therefore be allowed to modify their facilities without consideration of possible interference to analog stations where interference from other analog stations already exists.

Table 5A.

Interference Criteria for Co- and Adjacent Channels

Channel Offset	D/U Ratio, dB			
	Analog into Analog	DTV into Analog	Analog into DTV	DTV into DTV
-1 (lower adjacent)	-3	-17	-48	-42
0 (co-channel)	+28	+34	+2	+15
+1 (upper adjacent)	-13	-12	-49	-43

The evaluation of service and interference in Appendix B of the *Sixth Report and Order* considered taboo channel relationships for interference into DTV. However, the D/U ratios (approximately -60 dB) were such that they rarely if ever had an effect on the results, and the FCC rules adopted in the *Sixth Report*

and Order do not require attention to UHF taboo interference to DTV stations.

Receiving Antenna Pattern

The receiving antenna is assumed to have a directional gain pattern which tends to discriminate against off-axis undesired stations. This pattern is a planning factor affecting interference. The specific form of this pattern was chosen by a working group of the FCC Advisory Committee for Advanced Television. It is built into the service and interference computer program developed by the Broadcasters' Caucus and also used in the FCC program.

The discrimination, in relative volts, provided by the assumed receiving pattern is a fourth-power cosine function of the angle between the lines joining the desired and undesired stations to the reception point. One of these lines goes directly to the desired station, the other goes to the undesired station. The discrimination is calculated as the fourth power of the cosine of the angle between these lines but never more than represented by the front-to-back ratios identified in Table 6. When both desired and undesired stations are dead ahead, the angle is 0.0 giving a cosine of unity so that there is no discrimination. When the undesired station is somewhat off-axis, the cosine will be less than unity bringing discrimination into play; and when the undesired station is far off axis, the maximum discrimination given by the front-to-back ratio is attained.

Table 5B.

Interference Criteria for UHF Taboo Channels
(NC means not considered)

Channel Offset Relative to Desired Channel N	D/U Ratio, dB			
	Analog into Analog	DTV into Analog	Analog into DTV	DTV into DTV

N - 8	-32	-32	NC	NC
N - 7	-30	-35	NC	NC
N - 4	NC	-34	NC	NC
N - 3	-33	-30	NC	NC
N - 2	-26	-24	NC	NC
N + 2	-29	-28	NC	NC
N + 3	-34	-34	NC	NC
N + 4	-23	-25	NC	NC
N + 7	-33	-34	NC	NC
N + 8	-41	-43	NC	NC
N+14	-25	-33	NC	NC
N+15	-9	-31	NC	NC

Table 6.

Front-to-Back Ratios Assumed for Receiving Antennas

TV Service	Front-to-Back Ratios, dB		
	Low VHF	High VHF	UHF
Analog	6	6	6
DTV	10	12	14

III. THE FCC LONGLEY-RICE COMPUTER PROGRAM

The FCC computer program is available as Fortran code from the FCC's

internet site, www.fcc.gov. It is a complex program, and many of its options are available only by recompilation for each case of interest. The individual installing it should have computer programming skills and experience as a system administrator of the computer system on which it is to be installed because linking the data files, which occupy 1.6 gigabytes of disk space, will be a site-specific task. The FCC compiles and runs the program on Sun Microsystems SPARC 5 and UltraSPARC computers. In its present form it is most suitable for producing the information presented in Appendix B of the *Sixth Report and Order*, and the code is only now being modified to handle evaluation of new proposals.

Outline of Evaluation Procedure

The examination of each station proceeds as follows:

1) The area subject to calculation is boxed in latitude and longitude. This is done by going around the compass and finding the latitude and longitude of points at 5 degree azimuth increments on the bounding contour. The maxima and minima of the resulting list of latitudes and longitudes determine a coordinate box.

2) The coordinate box is divided into square cells of a chosen size which should be 2 km on a side or smaller, adjusting the coordinate box to be slightly larger if necessary to accommodate an integer number of cells. The cells must be an integer number of latitude seconds high and an integer number of longitude seconds wide.

3) The coordinates of 1990 census blocks falling inside each cell are retrieved along with the population of each block. From this information the total population and the coordinates of the cell centroid are determined for each cell.

4) The Longley-Rice propagation model is then applied as in Section I, Evaluation of Service, and Section II, Evaluation of Interference. The output information is organized as shown in Figure 1.

Figure 1.

Form of FCC Longley-Rice Program Output

```
Analysis of Analog Station IL SOME CITY, Channel 9

                                    POPULATION   AREA (sq km)
   within Noise Limited Contour        610288      14667.4
   not affected by terrain losses      604312      14165.4
   lost to NTSC IX                          0          0.0
   lost to additional IX by DTV             0          4.0
   lost to all IX                           0          4.0

Analysis of Paired DTV Station IL SOME CITY, Channel 32
   DTV ERP  133.7 kW
                                    POPULATION   AREA (sq km)
   within Noise Limited Contour        610288      14667.4
   not affected by terrain losses      606241      14378.2
   lost to NTSC IX                       1347         84.3
   lost to additional IX by DTV           425         44.2
   lost to DTV IX only                    425         44.2
   lost to all IX                        1772        128.5
   percent match DTV/NTSC                99.8         99.3
```

Longley-Rice Parameters

See Table 4 and accompanying text.

Identification of Affected Stations

Stations which may be a source of interference are identified as a function of distance and channel relationship. This is done independently for each cell. The criteria used to produce the evaluation of service and interference in Appendix B of the *Sixth Report and Order* are shown in Table 7.

Table 7.

Culling of Undesired Stations

Offset Relative to Desired Channel N	Maximum Distance from Cell to Undesired Stations, km			
	Analog into Analog	Digital into Analog	Analog into Digital	Digital into Digital
N - 8	35.0	35.0	25.0*	25.0*
N - 7	100.0	35.0	25.0*	25.0*
N - 5	NC	NC	NC	NC
N - 4	NC	35.0	25.0*	25.0*
N - 3	35.0	35.0	25.0*	25.0*
N - 2	35.0	35.0	25.0*	25.0*
N - 1	100.0	100.0	50.0	50.0
N (Co-channel)	300.0	300.0	250.0	250.0
N + 1	100.0	100.0	50.0	50.0
N + 2	35.0	35.0	25.0*	25.0*
N + 3	35.0	35.0	25.0*	25.0*
N + 4	35.0	35.0	25.0*	25.0*
N + 5	NC	NC	NC	NC
N + 7	100.0	35.0	25.0*	25.0*
N + 8	35.0	35.0	25.0*	25.0*
N +14	100.0	35.0	25.0*	25.0*
N +15	125.0	35.0	25.0*	25.0*

* These cell-to-undesired transmitter distances were used when examining taboo interference to digital service in the evaluation of service and interference appearing in Appendix B of the *Sixth Report and Order*. However, FCC rules do not require consideration of taboo interference except to analog stations.

Transmitting Antenna Patterns

The vertical patterns used in the FCC computer program are shown in Table 8. They

represent typical patterns and were used in computing the evaluation of service and interference in Appendix B of the *Sixth Report and Order.*

Table 8.

Vertical Pattern Assumed for Transmitting Antennas

ANGLE, Degrees	Gain in Vertical Plane, Relative Field Strength				
	Low VHF Analog and DTV	High VHF		UHF	
		Analog	DTV	Analog	DTV
0.75	1.000	1.000	1.000	1.000	1.000
1.50	1.000	0.950	0.970	0.740	0.880
2.00	0.990	0.860	0.940	0.520	0.690
2.50	0.980	0.730	0.890	0.330	0.460
3.00	0.970	0.600	0.820	0.220	0.260
3.50	0.950	0.470	0.730	0.170	0.235
4.00	0.930	0.370	0.650	0.150	0.210
5.00	0.880	0.370	0.470	0.130	0.200
6.00	0.820	0.370	0.330	0.110	0.150
7.00	0.740	0.370	0.280	0.110	0.150
8.00	0.637	0.310	0.280	0.110	0.150
9.00	0.570	0.220	0.280	0.110	0.150
10.00	0.480	0.170	0.250	0.110	0.150

IV. FREQUENTLY ASKED QUESTIONS

Q. Was the dipole factor adjustment applied only to UHF DTV stations, or was it applied also to UHF analog stations thus apparently changing the definition of the NTSC Grade B contour?

A: The dipole factor adjustment was applied to both analog and DTV signals for consistency in the required computations of service and interference. The *Sixth Report and Order* does

not modify previous rules relating to analog NTSC service.

Q. Section 73.622(f)(2)(ii) states that, for an application for authority to construct or modify DTV facilities without consideration of electromagnetic interference to other DTV or analog stations, a required condition is that "the proposed HAAT is equal to or less than the reference HAAT." Is this the HAAT for a specific radial?

A. The purpose of this requirement is generally to prevent a DTV station from obtaining an unusual site advantage due to terrain without further evaluation. The FCC is considering action to clarify the requirement and reducing the burden of any showings related to it.